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(54) **OPTICAL ELEMENT MANUFACTURING METHOD AND OPTICAL ELEMENT MANUFACTURING APPARATUS**

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(30) **Foreign Application Priority Data**

Jun. 29, 2010 (JP) 2010-147308

(57)

ABSTRACT

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C03B 23/00 (2006.01)

C03B 11/12 (2006.01)

C03B 11/16 (2006.01)

(52) **U.S. Cl.**

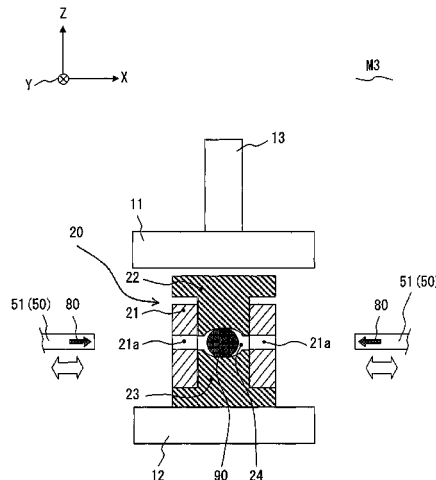
CPC **C03B 11/122** (2013.01); **C03B 11/16** (2013.01); **C03B 23/0013** (2013.01); **C03B 2215/66** (2013.01); **C03B 2215/69** (2013.01); **C03B 2215/72** (2013.01)

(58) **Field of Classification Search**

CPC C03B 2215/66; C03B 2215/69
See application file for complete search history.

The present invention provides an optical element manufacturing method including a first step of fixing an optical material by exerting a first weight different from a self weight of an upper die on the optical material positioned in a cavity between the upper die and a lower die, a second step of thereafter heating and softening the optical material by introducing a heated gas to an inside of the cavity, and a third step of thereafter molding an optical element by exerting a second weight larger than the first weight on the optical material within the cavity.

4 Claims, 11 Drawing Sheets



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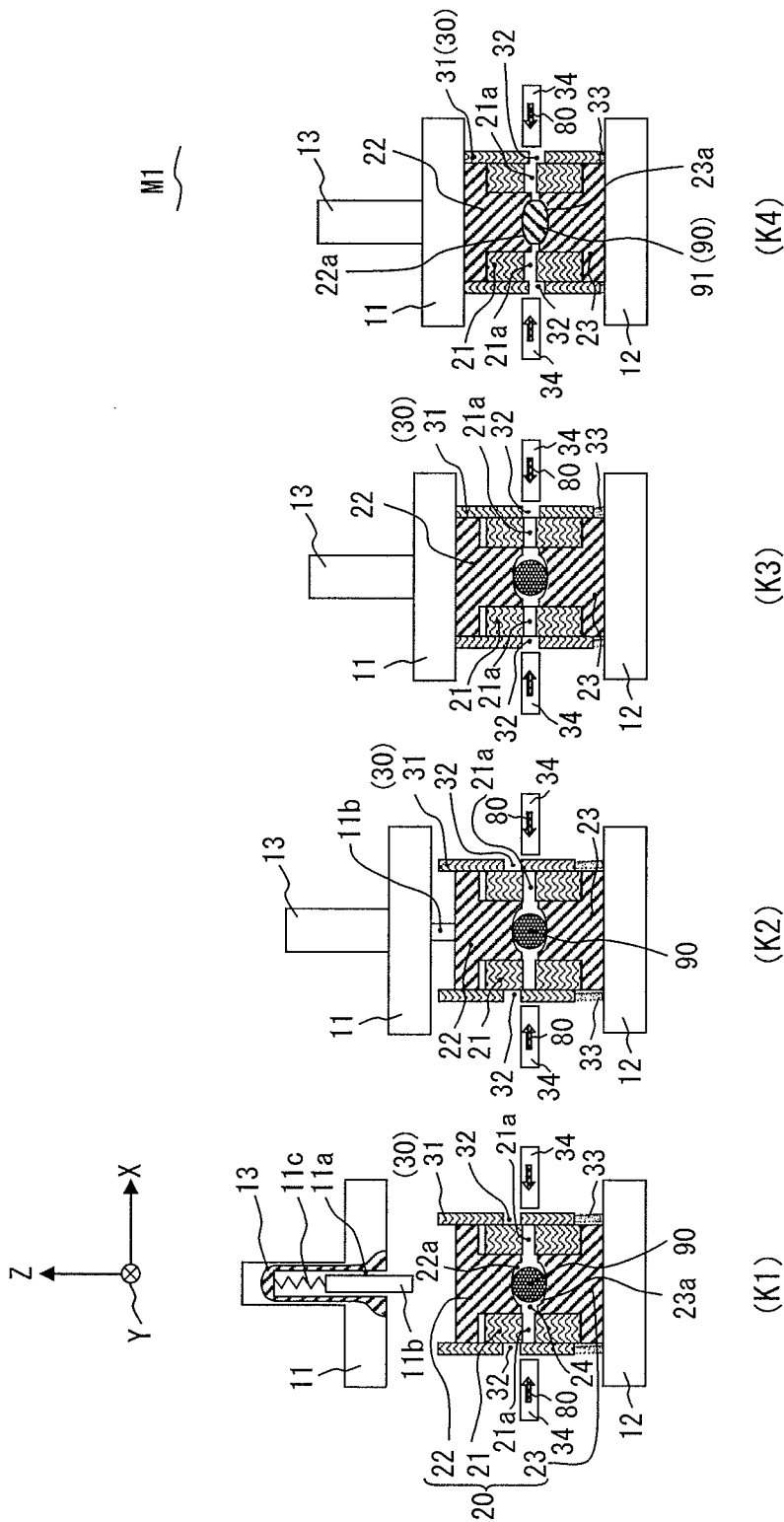
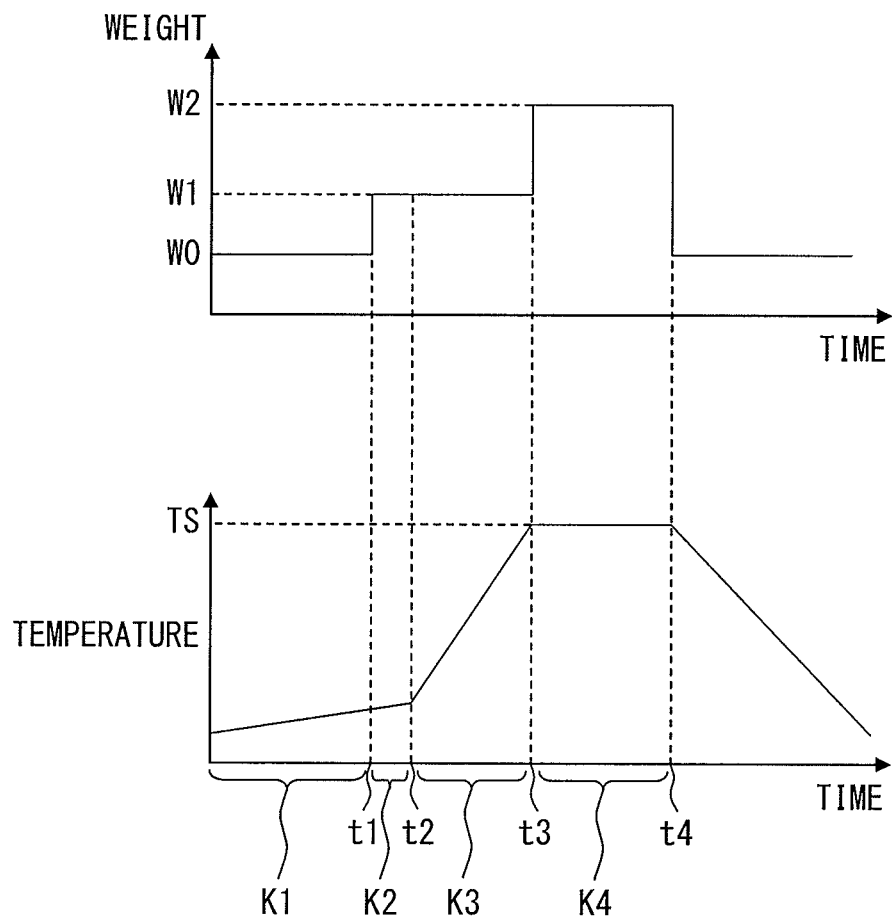


FIG. 1



F I G. 2

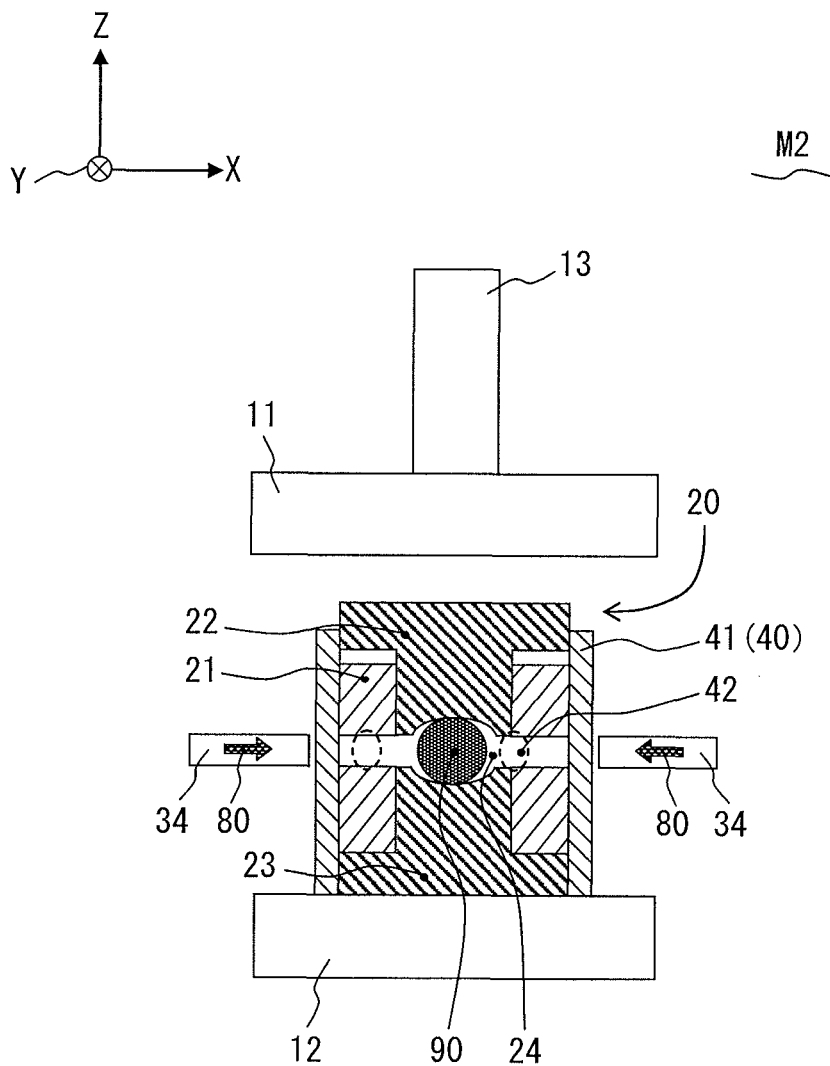


FIG. 3

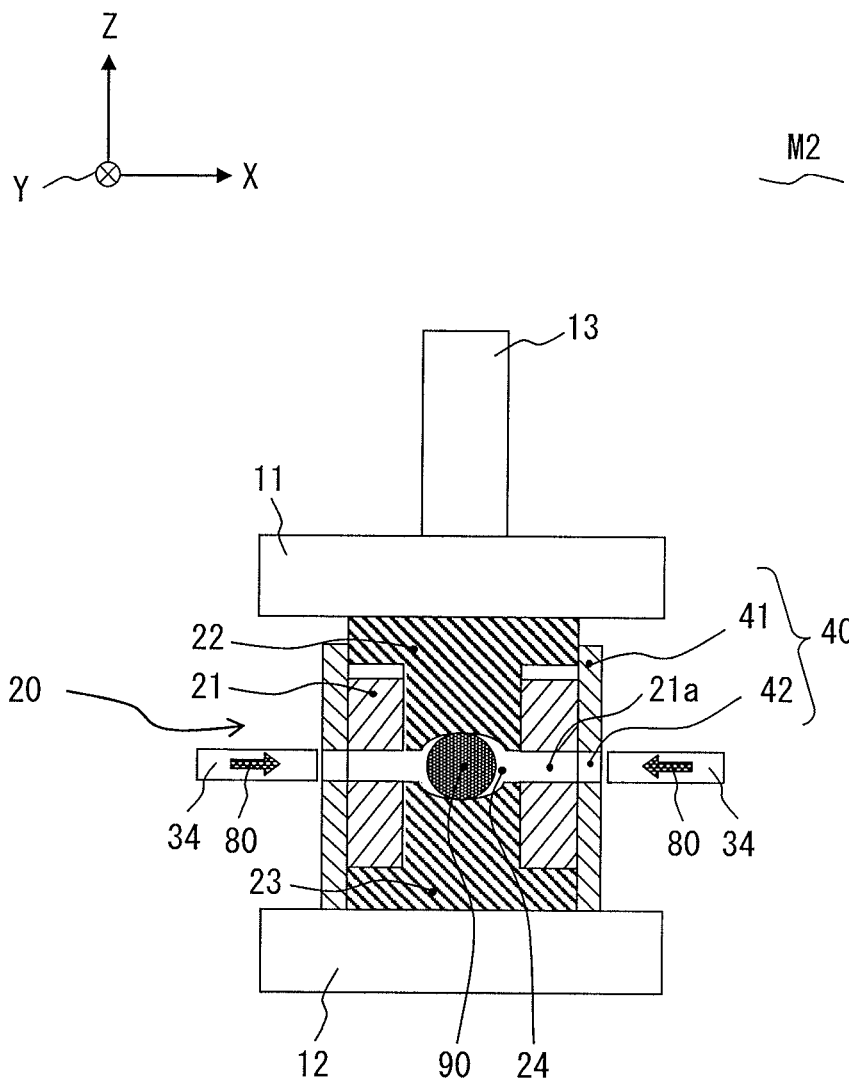


FIG. 5

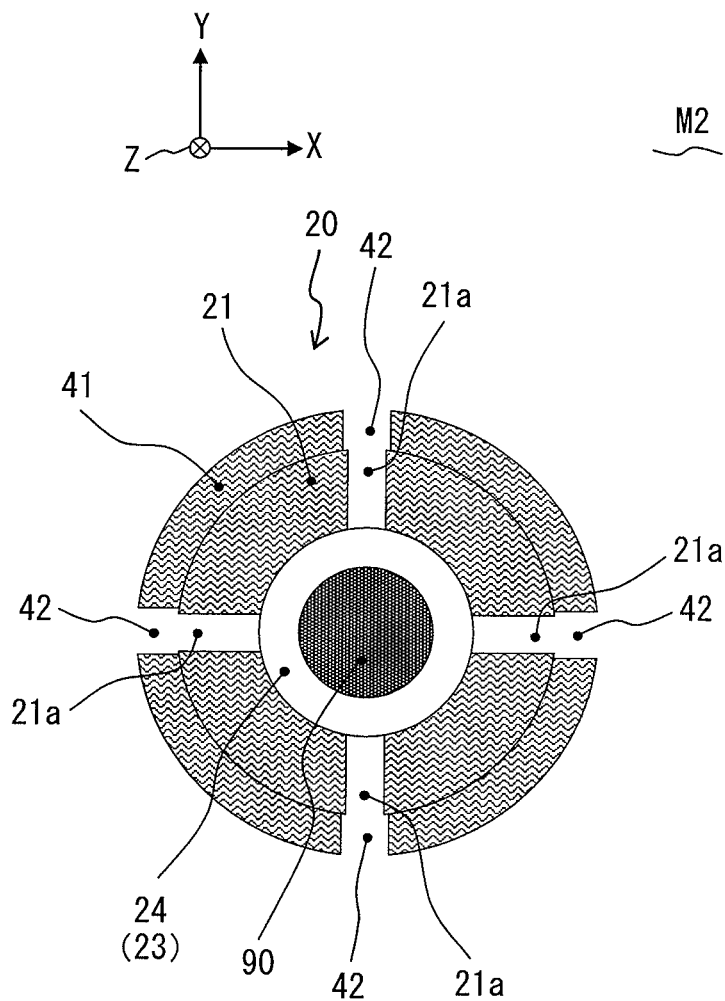


FIG. 6

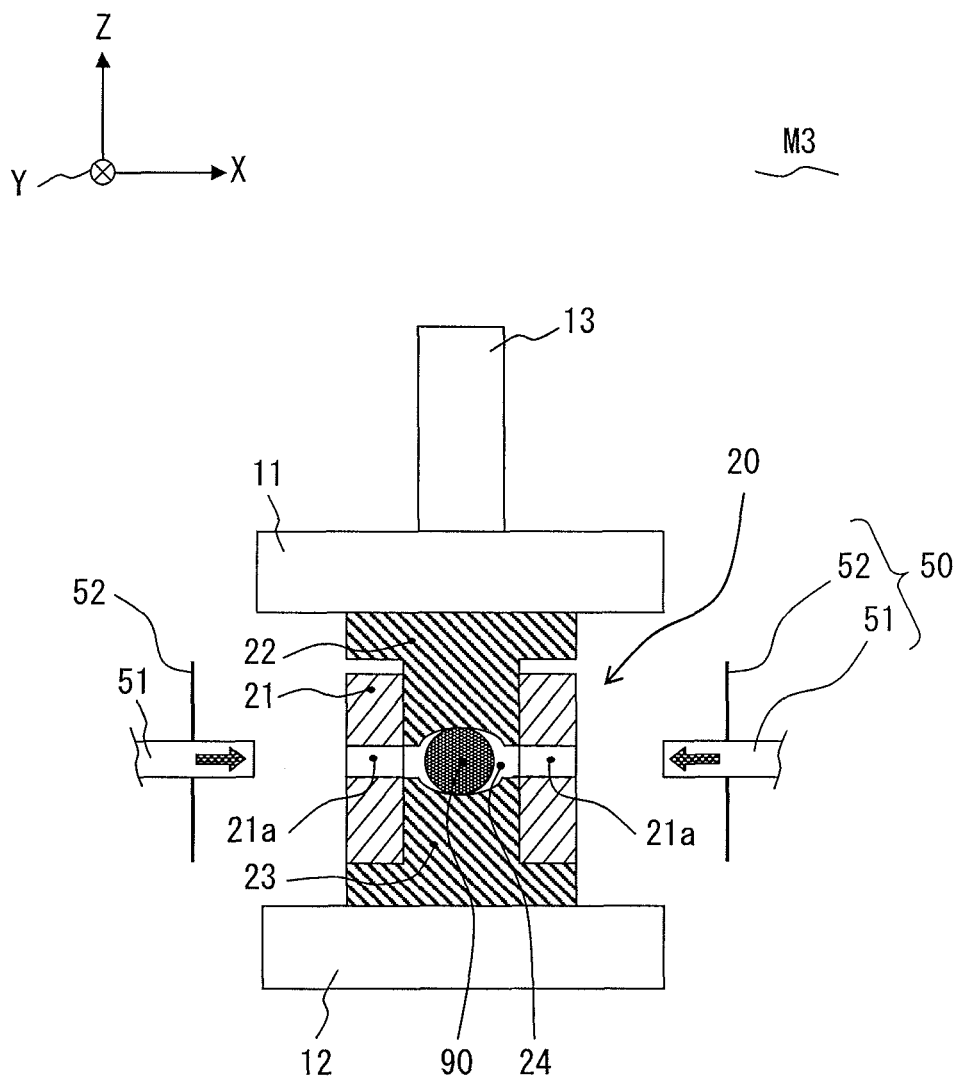


FIG. 8

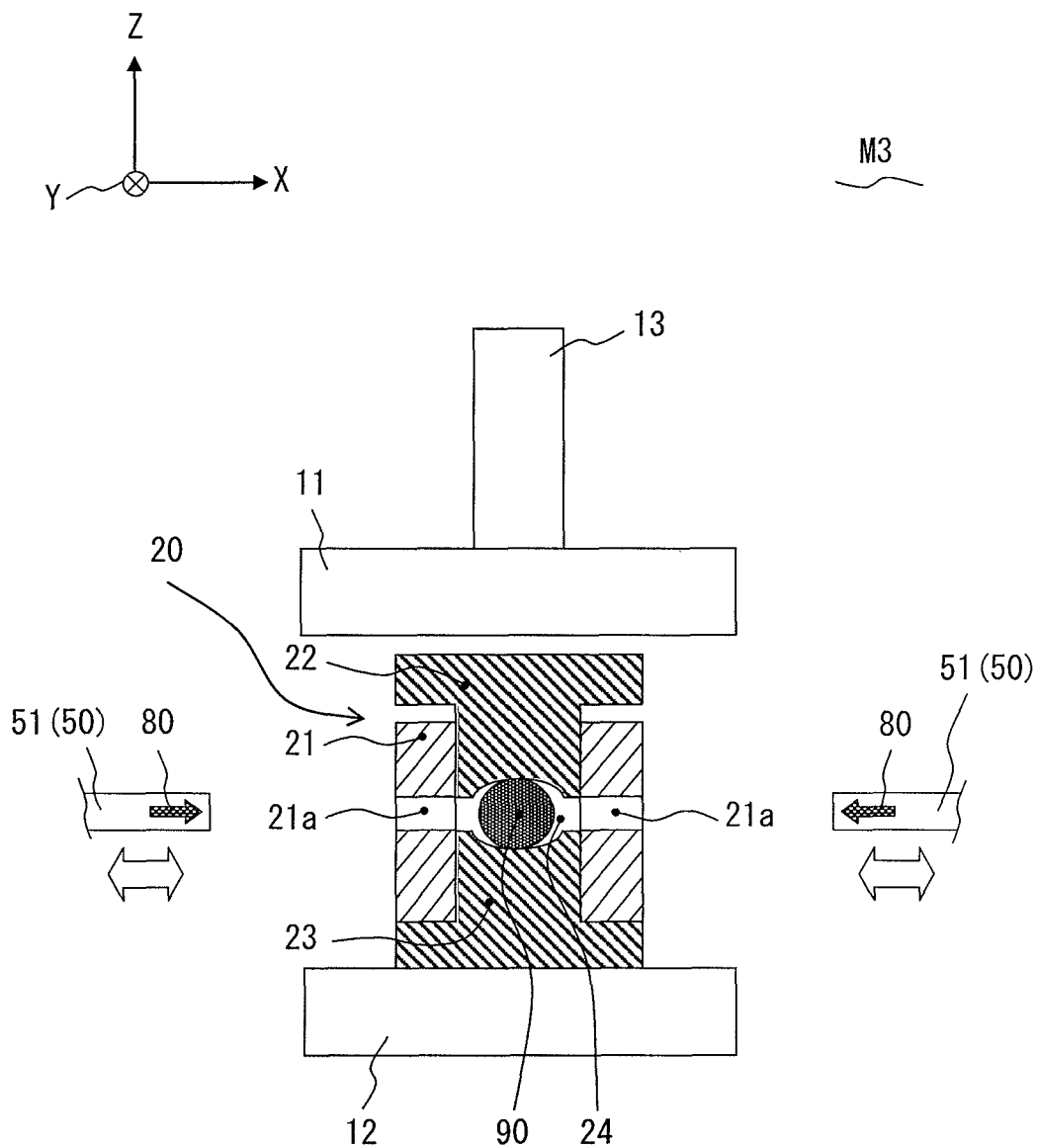


FIG. 9

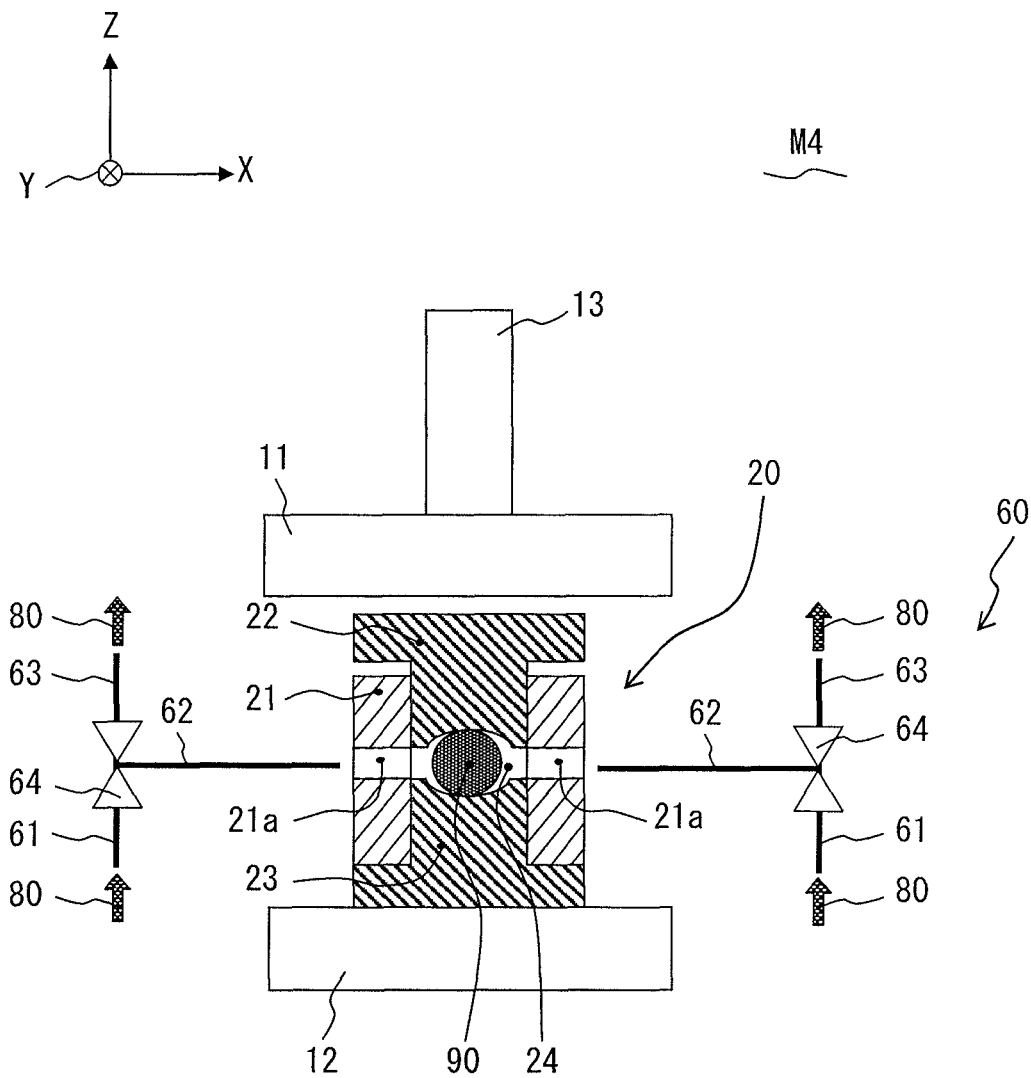


FIG. 10

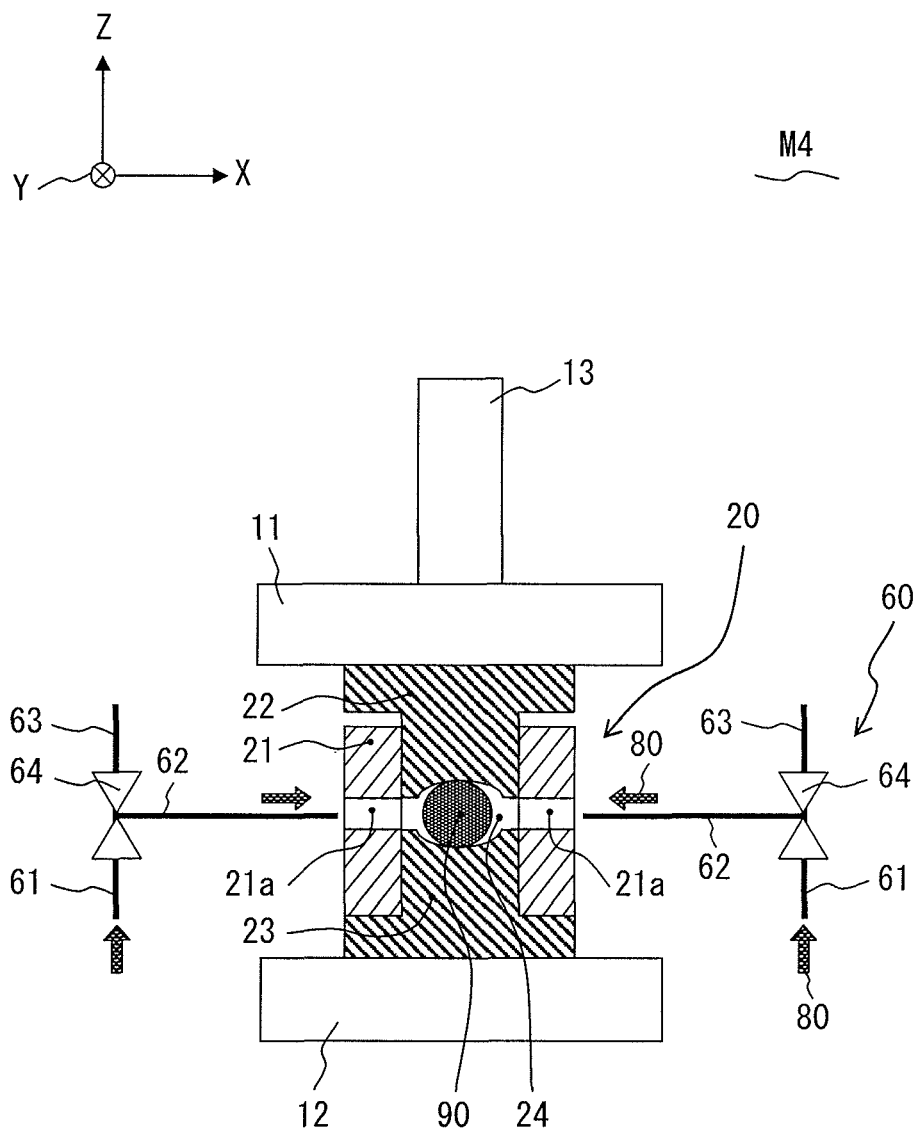


FIG. 11

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OPTICAL ELEMENT MANUFACTURING METHOD AND OPTICAL ELEMENT MANUFACTURING APPARATUS

CROSS-REFERENCE TO RELATED APPLICATION

This is a continuation application of PCT application No. PCT/JP2011/056882, filed on Mar. 23, 2011, which was not published under PCT Article 21(2) in English.

This application is based upon and claims the benefit of priority from prior Japanese Patent Application No. 2010-147308, filed on Jun. 29, 2010, the entire contents of which are incorporated herein by this reference.

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to an optical element manufacturing method and an optical element manufacturing apparatus.

2. Description of the Related Art

A technique of molding an optical element in a desired shape by heating and pressing a thermo-reversible optical material such as glass or the like within a molding die is known. This technique sometimes needs a lot of time to uniformly heat glass or the like due to a low thermal conductivity of the glass or the like if the glass or the like is attempted to be heated with heat conducted from a portion that makes contact with the molding die.

Therefore, Patent Document 1 discloses a technique of uniformly heating glass within a molding die by directly spraying a heated inactive gas onto the glass as auxiliary heating means.

PRIOR ART DOCUMENT

Patent Document

[Patent Document 1] Japanese Laid-Open Patent Publication No. 2008-120645

SUMMARY OF THE INVENTION

An object of the present invention is to provide an optical element manufacturing technique that can improve a heating efficiency by introducing a heated inactive gas into a molding die without degrading the quality of an optical element due to a misalignment or the like of an optical material within the molding die.

A first aspect of the present invention provides an optical element manufacturing method including a first step of fixing an optical material by exerting a first weight on the optical material positioned in a cavity within a molding die, a second step of thereafter heating and softening the optical material by introducing a heated gas to an inside of the cavity, and a third step of thereafter molding an optical element by exerting a second weight larger than the first weight on the optical material within the cavity.

A second aspect of the present invention provides an optical element manufacturing apparatus including pressurization means for pressurizing a molding die, gas introduction means for enabling a heated gas to be introduced into a cavity within the molding die, and control means for controlling the gas to be introduced into the cavity after fixing an optical material by exerting, on the optical material, a first

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weight that is smaller than a second weight exerted when the optical material accommodated in the cavity is molded.

A third aspect of the present invention provides an optical element molding die including a cylinder, an upper die and a lower die, which are respectively inserted from both ends of the cylinder and configure a cavity between mold surfaces facing within the cylinder, a gas introduction hole formed by penetrating into a wall surface of the cylinder at a position corresponding to the cavity, a sleeve in which the cylinder is inserted, and a gas supply hole that is formed by penetrating into a wall surface of the sleeve, and opens or closes the gas introduction hole depending on whether the sleeve is displaced either linearly or rotationally in an axial direction of the sleeve.

According to the present invention, an optical element manufacturing technique that can improve a heating efficiency by introducing a heated inactive gas to an inside of a molding die without degrading the quality of an optical element due to a misalignment or the like of an optical material within the molding die can be provided.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a sectional plan view illustrating one example of a configuration and actions of a manufacturing apparatus for executing an optical element manufacturing method according to an embodiment of the present invention in order of steps;

FIG. 2 is a schematic illustrating one example of actions of the manufacturing apparatus for executing the optical element manufacturing method according to the embodiment of the present invention;

FIG. 3 is a sectional plan view illustrating an example of a configuration of a manufacturing apparatus for executing an optical element manufacturing method according to another embodiment of the present invention;

FIG. 4 is a cross-sectional view of FIG. 3;

FIG. 5 is a sectional plan view illustrating one example of an operational state of the manufacturing apparatus for executing the optical element manufacturing method according to the another embodiment of the present invention;

FIG. 6 is a cross-sectional view of FIG. 5;

FIG. 7 is a sectional plan view illustrating an example of a configuration and actions of a manufacturing apparatus for executing an optical element manufacturing method according to a further embodiment of the present invention;

FIG. 8 is a sectional plan view illustrating an example of a configuration and actions of the manufacturing apparatus for executing the optical element manufacturing method according to the further embodiment of the present invention;

FIG. 9 is a sectional plan view illustrating a modification example of the configuration and the actions of the manufacturing apparatus for executing the optical element manufacturing method according to the further embodiment of the present invention;

FIG. 10 is a sectional plan view illustrating an example of a configuration and actions of a manufacturing apparatus for executing an optical element manufacturing method according to a still further embodiment of the present invention; and

FIG. 11 is a sectional plan view illustrating an example of a configuration and actions of the manufacturing apparatus

for executing the optical element manufacturing method according to the still further embodiment of the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

In one aspect of embodiments, a heated gas is introduced to an inside of a cavity after a molding material is sandwiched by upper and lower dies with a weight that does not move an optical material when the heated gas is introduced to the inside of the cavity of a molding die, and does not damage the optical material.

Additionally, a gas introduction path is shut off in order not to introduce a gas such as a heated gas or a low-temperature gas in the external atmosphere of the molding die into the cavity when the weight is released, so that the molding material within the molding die is prevented from being misaligned, or a temperature within the cavity is prevented from dropping.

Namely, the optical material remains stationary at a specified position and is efficiently heated without being moved from the specified position due to a dynamic pressure or the like of the heated gas introduced to the inside of the cavity. As a result, a satisfactory optical element can be obtained.

Embodiments according to the present invention are described in detail below with reference to the drawings.

The following description of the embodiments assumes that X, Y and Z directions are those illustrated in the drawings, and also assumes that the Z direction and an X-Y plane are a vertical direction and a horizontal plane, respectively.

Additionally, like numerals are denoted with like reference numerals, and redundant explanations are omitted in the following description of the embodiments.

First Embodiment

FIG. 1 is a sectional plan view illustrating one example of a configuration and actions of a manufacturing apparatus for executing an optical element manufacturing method according to an embodiment of the present invention in order of steps.

FIG. 2 is a schematic illustrating one example of the actions of the manufacturing apparatus for executing the optical element manufacturing method according to the embodiment of the present invention.

The manufacturing apparatus M1 according to this embodiment includes an upper plate 11 (pressurization means) and a lower plate 12, which face each other in the vertical direction, and an upper axis 13 for driving the upper plate 11 in the vertical direction.

Within the upper plate 11 and the lower plate 12, a heater not illustrated is buried. With the heater, each of the plates can be heated to a specified temperature.

On the lower plate 12, a molding die 20 is placed. At a circumference of the molding die 20, a control mechanism 30 (control means) to be described later is provided.

The molding die 20 includes a cylinder 21, and an upper die 22 and a lower die 23, which are inserted from top and bottom openings of the cylinder 21 so that they face each other.

Within the cylinder 21, a cavity 24 is formed between a mold surface 22a of the facing upper die 22 and a mold surface 23a of the lower die 23. The cavity 24 internally

accommodates an optical material 90 such as a glass pre-form or the like that is spherically molded in advance.

A wall surface of the cylinder 21 is provided with a plurality of gas introduction holes 21a (gas introduction means) (through holes) are formed at positions communicated with the inside of the cavity 24 by penetrating into positions symmetrical with respect to the Z axis.

In the case of the manufacturing apparatus M1 according to this embodiment, a control mechanism 30 including a sleeve 31 (first cylinder) in which the cylinder 21 is coaxially inserted, a plurality of gas nozzles 34 that are open and face the gas introduction holes 21a of the cylinder 21, and an axial direction driving spring 33 that is provided at the bottom end of the sleeve 31 and continuously presses the sleeve 31 in an upward direction where the sleeve 31 protrudes from the top end of the upper die 22 is arranged at the circumference of the molding die 20. In FIG. 1, only the sleeve 31 is denoted with the reference numeral (30) for the sake of convenience.

Note that the bottom end itself of the sleeve 31 may be configured to function as the axial direction driving spring 33 by forming a helical slit at the bottom end of the sleeve 31.

The gas nozzles 34 are configured, for example, with a torch heater. The gas nozzles 34 are configured to continuously emit, for example, an inactive gas 80 as a gas that is heated to a specified temperature to the gas introduction holes 21a of the molding die 20.

Additionally, the sleeve 31 has a plurality of gas supply holes 32 (first penetration holes) that are open at the same positions as the gas introduction holes 21a in the rotational direction of the Z axis.

The gas supply holes 32 move higher than the height position of the gas introduction holes 21a in a state where the sleeve 31 is protruded upward by the axial direction driving spring 33, so that the communication state between the gas introduction holes 21a and the gas nozzles 34 is shut off by the sleeve 31.

Additionally, when the top end of the sleeve 31, which is pressed downward by the upper plate 11, moves up to a position that matches the top end surface of the upper die 22, the gas supply holes 32 reach the same height as the gas introduction holes 21a of the cylinder 21. As a result, the gas nozzles 34 communicate with the gas introduction holes 21a, so that the heated inactive gas 80 is introduced to the inside of the cavity 24.

Namely, the control mechanism 30 according to this embodiment implements actions for switching a shutoff and a communication between the gas introduction holes 21a and the gas nozzles 34 by moving the sleeve 31 provided with the gas supply holes 32 upward or downward in conjunction with up and down movements of the upper plate 11.

In the case of this embodiment, a pin hole 11a is provided to penetrate into the upper plate 11 and the upper axis 13 in the axial direction at a center of the upper plate 11. The pin hole 11a internally accommodates a pressurization pin 11b (pressurization means) that protrudes from the bottom surface of the upper plate 11.

The top end of the pressurization pin 11b is fixed to the ceiling of the pin hole 11a via a pressurization spring 11c.

When the upper plate 11 is moved downward by the upper axis 13, the bottom end of the pressurization pin 11b initially touches the upper die 22 of the molding die 20 before the upper plate 11 touches the top end of the sleeve 31. As a result, a load (fixing weight W1 (first weight) that will be described later and fixes the optical material 90 by sand-

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wiching the optical material 90 between the upper die 22 and the lower die 23) is generated in a direction where the upper die 22 is made to approach the lower die 23.

Then, the pressurization pin 11b is pressed into the pin hole 11a as the upper plate 11 descends. In a state where the upper plate 11 touches the upper die 22, the pressurization pin 11b is completely pressed into the pin hole 11a.

As described above, in this embodiment, the pressurization pin 11b touches the upper die 22 before the descending upper plate 11 touches the sleeve 31, so that the fixing weight W1 is generated.

Accordingly, the fixing weight W1 can be set to a desired value by suitably setting a spring constant and a length of the pressurization spring 11c that supports the pressurization pin 11b.

In the case of this embodiment, settings are made such that the pressurization pin 11b exerts a specified fixing weight W1 on the upper die 22 at a height immediately before the gas supply holes 32 match the position of the gas introduction holes 21a when the sleeve 31 is pressed down by the descending upper plate 11, namely, at a position immediately before the inactive gas 80 is introduced from the gas nozzles 34 into the cavity 24.

One example of the actions of this embodiment is described below with reference to FIGS. 1 and 2.

Initially, the molding die 20 which internally accommodates the optical material 90 and to which the sleeve 31 is attached is placed on the lower plate 12 that is heated to a specified molding temperature (preparatory step K1).

At this time, only an upper die self weight W0 that is a self weight of the upper die 22 exerts on the optical material 90 within the molding die 20. Moreover, the optical material 90 is aligned so that its central position matches a central position of the cavity 24, namely, a central position (optical axis position) of the mold surface 22a and the mold surface 23a.

Additionally, the top end of the sleeve 31 protrudes from the top end surface of the upper die 22, and the gas supply holes 32 move to a position shifted upward from the gas introduction holes 21a. Accordingly, the cavity 24 is shut off from the gas nozzles 34 and the external atmosphere.

As described above, the gas introduction holes 21a are shut off by the sleeve 31 in the state where no load is externally exerted. Accordingly, the optical material 90 located at the specified central position of the cavity 24 within the molding die 20 is not misaligned by an influence such as the external atmosphere or the like.

Then, when the upper plate 11 that is heated to the specified molding temperature is moved down by the upper axis 13, the pressurization pin 11b that protrudes from the upper plate 11 initially touches the top end of the upper die 22, and the upper plate 11 descends to a position immediately before touching the sleeve 31. As a result, the fixing weight W1 is exerted on the upper die 22 (fixed timing t1) to fix the optical material 90 (fixing step K2 (first step)).

Additionally, when the upper plate 11 touches the top end surface of the upper die 22 by moving the upper plate 11 downward to press the sleeve 31, the gas supply holes 32 reach the positions of the gas introduction holes 21a (gas introduction start timing t2). As a result, the inactive gas 80 that is emitted from the gas nozzles 34 and heated to the specified temperature is sprayed onto the optical material 90 within the cavity 24, so that the optical material 90 starts to be heated (heating step K3 (second step)).

At this time, the optical material 90 is also heated by thermal conduction and a radiation heat from the upper plate 11 and the lower plate 12.

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In the case of this embodiment, the optical material 90 is fixed by the fixing weight W1 immediately before the inactive gas 80 is introduced from the gas nozzles 34, thereby securely preventing the optical material 90 from being misaligned from a specified central position of the cavity 24.

When the optical material 90 reaches a specified molding temperature TS, the optical material 90 starts to be molded by further moving the upper plate 11 downward by the upper axis 13, and by pressing the upper die 22 with a molding weight W2 (second weight) (molding press start timing t3). Then, the mold surface 22a of the upper die 22 and the mold surface 23a of the lower die 23 are transferred to the optical material 90, so that an optical element 91 is obtained (press molding step K4 (third step)).

At the time of this molding, the optical material 90 is aligned at the central position with high precision without being misaligned within the cavity 24 in the case of this embodiment. As a result, the optical material 90 deforms symmetrically with respect to the optical axis, whereby the optical element 91 of high quality having non-biased optical performance around the optical axis can be obtained.

Thereafter, the molding weight W2 exerted by the upper plate 11 is released, and the molding die 20 starts to be cooled down (molding press end timing t4). At this time, when the upper plate 11 moves up to separate from the sleeve 31, the sleeve 31 ascends, and the gas supply holes 32 move to a position shifted upward from the gas introduction holes 21a. In this way, the cavity 24 is restored to an externally shut state.

When the temperature of the molding die 20 drops to a specified temperature, the molding die 20 is disassembled to take out the optical element 91.

Note that a desired mold clamping weight may be exerted on the upper die 22 at the start of cooling down if needed.

As described above, in the case of the manufacturing apparatus M1 according to this embodiment, the sleeve 31 having the gas supply holes 32 for controlling opening/closing of the gas introduction holes 21a of the molding die 20 is moved upward and downward in conjunction with the upper plate 11. As a result, the heated inactive gas 80 is introduced into the cavity 24 after the specified fixing weight W1 is exerted to fix the optical material 90.

Accordingly, the heated inactive gas 80 is introduced to the inside of the cavity 24 and sprayed onto the optical material 90, whereby the optical material 90 can be uniformly heated to a molding temperature with high efficiency in a short time. Additionally, the optical material 90 is not moved despite being sprayed by the inactive gas 80, and an optical element 91 having a satisfactory optical performance can be efficiently obtained.

Here, an example of a method for deciding the fixing weight W1 and a method for supplying the inactive gas 80 from the gas nozzles 34 in this embodiment is described.

For example, the gas nozzles 34 are assumed to have a nozzle diameter ϕ of 1 mm to 4 mm in the case of this embodiment.

If the nozzle diameter ϕ of the gas nozzles 34 is too small, a flow velocity becomes too fast, and a dynamic pressure exerted on the optical material 90 onto which the inactive gas 80 is sprayed becomes high. Therefore, it is needed to fix the optical material 90 by sandwiching the material with a larger fixing weight W1.

In the meantime, if the nozzle diameter ϕ of the gas nozzles 34 is too large, the flow velocity becomes slow. Therefore, the optical material 90 is not fully heat-exchanged by the heated inactive gas 80.

For example, a flow quantity Q of the inactive gas **80** is assumed to be 10 L/min to 40 L/min.

If the flow quantity Q is too small, the flow velocity of the inactive gas **80** becomes slow, and the optical material **90** is not fully heat-exchanged. In contrast, if the flow quantity Q is too large, the flow velocity of the inactive gas **80** becomes too fast. Therefore, it is needed to fix the optical material **90** by sandwiching the material with a larger fixing weight **W1**.

One example of a method for deciding the fixing weight **W1** based on a size, a shape or the like of the optical material **90** is described next.

If not a point but a surface of the optical material **90** makes contact with the mold surfaces **22a**, **23a** by being elastically deformed by the weight, and if the optical material **90** is shaped like a sphere, assume

P : concentrated weight [N] (=fixing weight **W1**)

ν_1 : Poisson ratio of the optical material **90**

ν_2 : Poisson ratio of the mold surface **22a** (mold surface **23a**)

E_1 : longitudinal elasticity modulus [MPa] of the optical material **90**

E_2 : longitudinal elasticity modulus [MPa] of the mold surface **22a** (mold surface **23a**)

R_1 : curvature radius [mm] of the optical material **90**

R_2 : curvature radius [mm] of the mold surface **22a** (mold surface **23a**) ($1/R_2 = -1/(R_2)$ in a case of a concave surface, or $R_2 = \infty$ in a case of a flat surface).

In this case, the contact radius α [mm] with the mold surface **22a** (mold surface **23a**) is represented by the following equation (1) based on Hertz's formula.

$$\alpha = 3 \sqrt{\frac{\frac{3P}{4} \left(\frac{1-\nu_1^2}{E_1} + \frac{1-\nu_2^2}{E_2} \right)}{\left(\frac{1}{R_1} + \frac{1}{R_2} \right)}} \quad (1)$$

Here, the optical material **90** is not fully deformed when being heated if the contact radius α is small, or the surface of the optical material **90** cracks if the contact radius α is too large. Therefore, a satisfactorily molded product such as an optical element **91** or the like cannot be obtained.

Accordingly, it is desirable in the case of this embodiment that the contact radius α between the mold surface **22a** (mold surface **23a**) and the optical material **90** is, for example, 0.05 mm to 0.3 mm. Accordingly, the fixing weight **W1** is set to, for example, a range from approximately 1 kgf to 50 kgf in this embodiment.

More desirably, the contact radius α is approximately 0.1 mm to 0.2 mm. In this case, the fixing weight **W1** is set to, for example, a range from approximately 5 kgf to 30 kgf.

Namely, in the case of this embodiment, the fixing weight **W1** by which a force that can fully fix the optical material **90** is obtained in a range where the optical material **90** is not damaged is decided according to the flow quantity Q of the heated inactive gas **80**, the shape of the optical material **90** or the like.

Note that the length of time needed for the press molding step **K4** may be reduced by promoting the optical material **90** to deform in the heating step **K3** with an increase of the fixing weight **W1** to a largest value within the range where the optical material **90** is not damaged.

Alternatively, the optical material **90** may be promoted to deform during the heating step **K3** by exerting a third weight larger than the fixing weight **W1** during the heating step **K3** in the range where the optical material **90** is not damaged.

FIG. 3 is a sectional plan view illustrating an example of a configuration of a manufacturing apparatus for executing an optical element manufacturing method according to a second embodiment of the present invention, whereas FIG. 4 is a cross-sectional view of FIG. 3.

FIG. 5 is a sectional plan view illustrating one example of an operational state of the manufacturing apparatus for executing the optical element manufacturing method according to the second embodiment of the present invention, whereas FIG. 6 is a cross-sectional view of FIG. 5.

The manufacturing apparatus **M2** according to this embodiment is different from the above described manufacturing apparatus **M1** in that a rotatable sleeve **41** (second cylinder) in which the cylinder **21** of the molding die **20** is coaxially inserted and which has gas supply holes **42** (second penetration holes) formed at positions of the same height and in the same circumferential direction as the gas introduction holes **21a** of the cylinder **21** is used as a control mechanism **40** (control means).

In this case, in order to fully secure a stroke by the upper plate **11** at the time of press molding, the height of the rotatable sleeve **41** is set to be shorter than a distance between both end surfaces of the upper die **22** and the lower die **23** in the molding die where the optical material **90** is accommodated.

In the case of the control mechanism **40** of the manufacturing apparatus **M2** according to the second embodiment, the rotatable sleeve **41** is rotated about the Z axis by a rotational mechanism not illustrated in conjunction with up and down movements of the upper plate **11**, thereby controlling a position where the gas introduction holes **21a** of the cylinder **21** and the gas supply holes **42** of the rotatable sleeve **41** match, and a position where the gas supply holes **42** shift from the gas introduction holes **21a**. In this way, whether or not to introduce the inactive gas **80** from the gas nozzles **34** into the cavity **24** of the molding die **20** is controlled.

Namely, in a standby state before the molding, the rotatable sleeve **41** is rotated to the position illustrated in FIGS. 3 and 4 to shut off the gas introduction holes **21a**, thereby preventing the optical material **90** from being misaligned by the external atmosphere or the like.

Then, in a state where the upper plate **11** descends and touches the top end surface of the upper die **22** and the optical material **90** is fixed between the upper die **22** and the lower die by exerting a specified fixing weight **W1** on the upper die **22**, the rotatable sleeve **41** is rotated to a position where the gas supply holes **42** match the gas introduction holes **21a** as illustrated in FIGS. 5 and 6. As a result, the heated inactive gas **80** is introduced from the gas nozzles **34** into the cavity **24** via the gas supply holes **42** and the gas introduction holes **21a**, and the gas is sprayed onto the optical material **90**, so that the optical material **90** is heated.

Additionally, when the weight exerted by the upper plate **11** is released, the rotatable sleeve **41** is again rotated to make the positions of the gas introduction holes **21a** and the gas supply holes **42** mismatch, thereby shutting off the introduction path of the inactive gas **80** into the cavity **24**.

As described above, also in the case of the manufacturing apparatus **M2** according to this embodiment, the optical material **90** can be securely prevented from moving from a specified position when the optical material **90** positioned within the cavity **24** is heated by being sprayed by the

inactive gas **80** having a high temperature. Consequently, effects similar to those of the above described first embodiment can be achieved.

Furthermore, in the case of the manufacturing apparatus M2 according to the second embodiment, the top end portion of the rotatable sleeve **41** does not protrude above the upper die **22** of the molding die **20**. Accordingly, the second embodiment has an advantage such that the fixing weight **W1** can be exerted by a press operation of the upper plate **11** itself without providing a member such as the pressurization pin **11b** or the like on the upper plate **11**.

Third Embodiment

FIGS. **7** and **8** are sectional plan views illustrating an example of a configuration and actions of a manufacturing apparatus for executing an optical element manufacturing method according to a third embodiment of the present invention.

The manufacturing apparatus M3 according to the third embodiment is different from the above described first embodiment in that a control mechanism **50** (control means) composed of movable gas nozzles **51** and a movable shutoff plate **52** is provided at a circumference of a space, in which the molding die **20** is arranged, between the upper plate **11** and the lower plate **12**.

Namely, in the case of this manufacturing apparatus M3, by being supported by a driving mechanism not illustrated, the movable gas nozzles **51** of the control mechanism **50** are displaced between a position for coaxially facing and approaching the gas introduction holes **21a** of the cylinder **21** in the molding die **20** and a position separate from the gas introduction holes **21a**.

These movable gas nozzles **51** are configured, for example, with a torch heater, and continuously emit an inactive gas **80** that is heated to a specified molding temperature.

Additionally, the movable shutoff plate **52** that can shut off the inactive gas **80** emitted from the movable gas nozzles **51** to the gas introduction holes **21a** by being displaced in the Y direction vertical to the paper sheets of FIGS. **7** and **8** is arranged on the course of the displacement of the movable gas nozzles **51**.

In the case of this manufacturing apparatus M3, when the fixing weight **W1** is not exerted by the upper plate **11** on the upper die **22** and the optical material **90** (the state illustrated in FIG. **7**), the movable gas nozzles **51** are retracted to a position separate from the gas introduction holes **21a**, and the movable shutoff plate **52** advances between the retracted movable gas nozzles **51** and the gas introduction holes **21a** of the cylinder **21**. In this way, the inactive gas **80** emitted from the movable gas nozzles **51** to the gas introduction holes **21a** is shut off.

As a result, the optical material **90** within the cavity **24** is prevented from being misaligned from a specified position before the upper plate **11** touches the upper die **22** of the molding die **20** placed on the lower plate **12**.

Thereafter, at a time point when the upper plate **11** is moved down by the upper axis **13** and touches the upper die **22** to exert the fixing weight **W1**, the movable shutoff plate **52** is retracted from the moving path of the movable gas nozzles **51**. At the same time, the movable gas nozzles **51** are made to approach the gas introduction holes **21a**, the inactive gas **80** that is heated to the specified temperature is sprayed onto the optical material **90** within the cavity **24** from the movable gas nozzles **51**, and the optical material **90** is heated to the molding temperature. Thereafter, press

molding for pressing the upper die **22** with the molding weight **W2** by further moving down the upper plate **11** is performed.

When the upper plate **11** separates from the upper die **22** after the press molding, the movable gas nozzles **51** are retracted and the movable shutoff plate **52** advances to shut off the inactive gas **80** emitted from the movable gas nozzles **51**.

As described above, also in the case of the third embodiment, the inactive gas **80** that is heated to the specified temperature can be sprayed onto the optical material **90** within the cavity **24** in the state where the optical material **90** is fixed by exerting the specified fixing weight **W1** on the upper die **22** from the upper plate **11**. As a result, the optical material **90** can be uniformly heated to a specified molding temperature with high efficiency in a short time, and the optical material **90** can be securely prevented from being misaligned when the inactive gas **80** is sprayed onto the optical material **90**, whereby an optical element **91** of high quality can be obtained.

Additionally, the manufacturing apparatus M3 according to the third embodiment also has an advantage such that there is no need to arrange a special component on the sides of the upper plate **11** and the molding die **20**, leading to simplification of a configuration of the molding die **20**.

The above described example refers to the case where the inactive gas **80** is shut off by using the movable shutoff plate **52**. However, introduction of the inactive gas **80** into the cavity **24** can be substantially shut off, for example, by sufficiently separating the movable gas nozzles **51** from the gas introduction holes **21a** as illustrated in FIG. **9** without providing the movable shutoff plate **52**. In either case, the flow quantity of the inactive gas **80** introduced to the inside of the cavity **24** in the above described first step (fixing step **K2**) can be made smaller than that in the above described second step (heating step **K3**) (including also a case where the flow quantity of the inactive gas **80** introduced to the inside of the cavity **24** in the first step is 0).

Fourth Embodiment

FIGS. **10** and **11** are sectional plan views illustrating an example of a configuration and actions of a manufacturing apparatus for executing an optical element manufacturing method according to a fourth embodiment of the present invention.

The manufacturing apparatus M4 according to the fourth embodiment is different from the above described third embodiment in that a control mechanism **60** (control means) composed of gas supply tubes **61**, gas supply nozzles **62**, gas bypass nozzles **63** and switch valves **64** is arranged as a replacement for the above described control mechanism **50**.

Namely, in the case of the manufacturing apparatus M4 according to this embodiment, the gas supply tubes **61** are configured, for example, with a torch heater, and configured to continuously supply an inactive gas **80** that is heated to a specified molding temperature to the gas supply nozzles **62** or the gas bypass nozzles **63** via the switch valves **64**.

The gas supply nozzles **62** are fixedly arranged at positions coaxially facing the gas introduction holes **21a** adjacently to the gas introduction holes **21a** of the cylinder **21** in the molding die **20** placed on the lower plate **12**.

In other words, the molding die **20** is aligned so that the gas introduction holes **21a** of the cylinder **21** match the tips of the gas supply nozzles **62** when the molding die **20** is placed on the lower plate **12**.

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Additionally, the gas bypass nozzles **63** are provided to be open in a direction that deviates from the molding die **20** placed on the lower plate **12**, and to emit the heated inactive gas **80** in a direction where the molding die **20** is not sprayed.

Namely, in the case of this embodiment, the heated inactive gas **80** is supplied from the gas supply tubes **61** to the gas bypass nozzles **63** by the switch valves **64** as illustrated in FIG. **10** if the fixing weight **W1** is not exerted on the molding die **20** in the control mechanism **60**. Moreover, the inactive gas **80** is led to a direction that deviates from the molding die **20**.

In the meantime, upon detecting that the optical material **90** is sandwiched between the upper die **22** and the lower die **23** with a predetermined force by exerting the specified fixing weight **W1** on the upper die **22** of the molding die **20** from the upper plate **11** at a stage before the molding, the switch valves **64** activate to lead the heated inactive gas **80** to the cavity **24** via the gas supply nozzles **62** facing towards the gas introduction holes **21a** as illustrated in FIG. **11**, so that the optical material **90** is heated.

When the weight exerted on the upper plate **11** is released, the switch valves **64** reactivate to lead the heated inactive gas **80** in a direction that deviates from the molding die **20** via the gas bypass nozzles **63**.

Also in the case of this fourth embodiment, effects similar to those of the above described third embodiment can be obtained, and at the same time, the supply direction of the heated inactive gas **80** to the gas supply tube **61**, the gas supply nozzles **62** and the gas bypass nozzles **63**, which are installed stationarily, is only switched by the switch valves **64** in conjunction with up and down movements of the upper plate **11**. Accordingly, the fourth embodiment has an advantage such that a movable part other than the switch valve **64** is not needed, leading to simplification of a configuration.

As described above, according to the embodiments of the present invention, a heating efficiency achieved by introducing the heated inactive gas **80** to the inside of the molding die **20** can be improved without degrading the quality of the optical element **91** due to a misalignment or the like of the optical material **90** within the molding die **20**.

The present invention is not limited to the above described embodiments, and can be diversely modified within a scope that does not depart from the gist of the present invention as a matter of course.

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For example, the above described embodiments refer to the configurations where the torch heater is used as the mechanism for heating the inactive gas **80**, the heated inactive gas **80** is continuously supplied, the supply path of the inactive gas **80** is shut off, and the supply positions and the direction of the gas are controlled. However, the present invention is not limited to these configurations. For example, heating, and emission and supply operations themselves of the inactive gas **80** may be switched on/off in conjunction with up and down movements of the upper plate **11**.

What is claimed is:

1. An optical element manufacturing method, comprising: placing an optical material in a cavity of a mold comprising upper and lower dies, the upper die exerting a self weight on the optical material; during a first period, exerting a first weight, greater than the self weight exerted by the upper die, on the optical material while the optical material is positioned in the cavity between the upper die and the lower die; during a second period, heating and softening the optical material by introducing a heated gas into the cavity at a first flow rate; and during a third time period, molding the optical material into the optical element by exerting a second weight, larger than the first weight, on the optical material while introducing the heated gas into the cavity at a second flow rate which is higher than the first flow rate; wherein the heated gas is introduced into the cavity during the second time period by moving a movable gas nozzle from a first position remote from the cavity to a second position closer to the cavity than the first position.
2. The optical element manufacturing method according to claim 1, wherein the gas is introduced into the cavity from a gas source located outside of the cavity via a flow path and the flow path is shut off during the first period.
3. The optical element manufacturing method according to claim 1, wherein the optical material is further deformed during the second time period by exerting a third weight, larger than the first weight, on the optical material.
4. The optical element manufacturing method according to claim 1, wherein the movable gas nozzle is located in the first position during the first time period.

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